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METHOD FOR INSPECTING INFERIORITY IN SHAPE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method for inspecting inferiority in shape of such objects as semiconductor chips and lead wires, which is employed in semiconductor manufacturing processes, and more particularly, to a method for inspecting inferiority in shape of an object, in which shape inferiority of the object is inspected through a grayscale comparison operation, to thereby reduce the time required for inspection and lower the dependence upon a skilled worker in performing the inspection.

2. Description of the Related Art

A two-dimensional measuring method for measuring the shape of an object has widely been used for production automation of goods such as semiconductor devices. According to prior art, a boundary area for measuring the shape of an object is detected and abnormality in the shape of the object is analytically discriminated using a predetermined measuring algorithm, in order to inspect whether the object is normal or abnormal in shape.

However, since the conventional method requires to pass through all the above procedures with respect to all the inspection objects, a large amount of time is consumed, and an inspection algorithm appropriate for shape of the inspection object should be implemented.

FIG. 1 is a schematic view for explaining an object shape inferiority inspection method by means of a conventional measurement-comparison method. As depicted, the conventional object shape inferiority inspection method employs an algorithm for inspecting inferiority in shape of the object

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through the two steps of 'measurement' and 'comparison' according to the measurement-comparison method.

First, shape data on an inspection object 12 is measured using distribution of brightness of an image. For example, as shown in FIG. 1, a size "*e*" in a certain direction is measured in terms of the external appearance of the inspection object 12. Then, the measured data is compared with a reference data "*d*" of a reference model 11. If the measured size "*e*" is within the range of an allowable error of $\pm\Delta d$ with respect to the reference data "*d*," it is discriminated that the inspection object 12 is normal in shape. Otherwise, it is discriminated that the inspection object 12 is abnormal in shape.

Although the object shape inferiority inspection method using the conventional measurement-comparison method has shown a precision in the unit of subpixel, the above processes should be repeated with respect to all measuring elements representing characteristics in shape of the inspection object. As a result, a large amount of time is needed for calculation in compliance with a measurement algorithm. A shape inferiority inspection is performed in such a manner that only a part of all the measuring elements indicating the characteristics in shape of the object is measured in order to reduce an inspection time. Accordingly, skill and experience are very important in setting the measuring elements to be measured, to accurately detect the shape inferiority. That is, the inspection is highly dependent on a skilled worker.

SUMMARY OF THE INVENTION

To solve the above problems, it is an object of the present invention to provide a method for inspecting inferiority in shape of an object in which even

an unskilled worker can easily detect inferiority in shape of an object.

To accomplish the above object of the present invention, there is provided a method for inspecting inferiority in shape of an object through an inspection image obtained from an inspection object, the object shape inferiority inspection method comprising the steps of preparing at least one reference image for judgment as to shape inferiority in the inspection object considering an allowable error for shape; obtaining the inspection image from the inspection object; comparing grayscales for each one part, at least, of portions where the reference image and the inspection image mutually correspond; and judging whether inferiority in shape of the inspection object exists, based on the result of the grayscale comparison.

It is preferable that said grayscale comparison step comprises comparison of brightness values of each corresponding pixel of the inspection image and the reference image.

Preferably, said reference image preparation step comprises the sub-steps of: obtaining a range of brightness for the pixel corresponding to a range of allowable error for a position value on a boundary line, on the basis of a function relation with a change in brightness of the pixel according to a change in a position value on the boundary line of the inspection object; and establishing and registering a minimum image whose brightness value is a minimum value of the brightness range and a maximum image whose brightness value is a maximum value of the brightness range, as the reference image.

It is preferable that said function relation considers existence of pixel noise; for example, said function relation is accomplished from addition of or subtraction of the pixel noise.

It is effective that the grayscale comparison operation for said grayscale comparison step is expressed as the following equation:

$$C(Q;U,L) = \Pi[\, l(i,j) \le q(i,j) \le u(i,j)]$$

wherein $C(Q; U,L)$ is a function for discriminating shape inferiority in an object, using the reference images U and L, when the inspection image Q is given, $l(i, j)$ is a brightness value of a pixel positioned at a coordinate (i, j) of the minimum image L, $q(i, j)$ is a brightness value of a pixel positioned at a coordinate (i, j) of the inspection image Q, and $u(i, j)$ is a brightness value of a pixel positioned at a coordinate (i, j) of the maximum image U.

It is also effective that said inspection image and said reference image are expressed in terms of grayscale.

BRIEF DESCRIPTION OF THE DRAWINGS

The object and other advantages of the present invention will become more apparent by describing in detail the structures and operations of the present invention with reference to the accompanying drawings, in which:

FIG. 1 is a schematic view for explaining an object shape inferiority inspection method by means of a conventional measurement-comparison method;

FIG. 2 is a schematic view for explaining an object shape inferiority inspection method by means of a grayscale comparison method according to the present invention;

FIGs. 3a and 3b are graphical views for explaining a change in brightness of a pixel according to a position of a boundary line of an inspection

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object;

FIGs. 4a and 4b are graphical views for explaining a process of obtaining a brightness range including an allowable error considering that pixel noise exists; and

FIG. 5 shows an image of a lead frame which is used for a shape inferiority inspection.

DETAILED DESCRIPTION OF THE INVENTION

A preferred embodiment of the present invention will be described in detail with reference to the accompanying drawings.

FIG. 2 is a schematic view for explaining an object shape inferiority inspection method by means of a grayscale comparison method according to the present invention.

Referring to FIG. 2, an object shape inferiority inspection method by means of a grayscale comparison method according to the present invention, is conducted as follows:

First, as a reference for a shape inferiority inspection, a reference image 22 is established and registered, in which the reference image 22 is expressed as a brightness value of each pixel expressed in terms of a grayscale with respect to a reference model 21. The reference image 22 includes a minimum image composed of pixels having minimum brightness values within an allowable error range for shape and a maximum image composed of pixels having maximum brightness values within an allowable error range for shape.

Then, a brightness value of each pixel in an inspection image 24 of an inspection object 23 which is obtained via a camera (not shown) is compared

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with that of the established and registered reference image 22, in order to inspect whether the inspection object 23 is normal or abnormal in shape. If a brightness value of each pixel in an inspection image 24 is within the allowable error range of the brightness value in each corresponding pixel designated by the minimum image and the maximum image which are the reference image 22 of the reference model 21, it is discriminated that the inspection object is normal in shape. Otherwise, it is discriminated that the inspection object is abnormal in shape.

The reference image 22 which is used as a shape inferiority inspection reference is obtained through the following procedure:

FIGs. 3a and 3b are graphical views for explaining a change in brightness of a pixel according to a position of a boundary line forming the shape of an inspection object.

In FIG. 3a, a circle P indicated in a dotted line represents a pixel unit, and oblique lines l_1, l_2 and l_3 mean boundary lines of an inspection object 23. Assuming that a position value *X* is 0(zero) in a case that the boundary line l_1 is circumscribed with a pixel *P* and the pixel *P* is not included in the inspection object 23, a position value *X* is 0.5 in a case that the boundary line l_2 passes through the central area of the pixel *P*, and a position value is 1 in a case that the boundary line l_3 is circumscribed with the pixel P and the pixel P is completely included in the inspection object 23, a brightness "*I*" with respect to the position value "*X*" varies as shown in FIG. 3b. Thus, if a brightness value "*b*" is given, a position "*X*" of a boundary line can be estimated at the corresponding area through the graph of FIG. 3b. Based on the bright values, it can be discriminated whether a pixel belongs to an inspection object, the former does not belong to the latter, or the former exists on a boundary line of

the latter.

In a case that the boundary line l_2 of the inspection object 23 passes through the central area of a unit pixel P, a method for discriminating whether the boundary line l_2 of the inspection object is positioned within the allowable error range ΔX is as follows:

Through the pixel brightness graph $I(x)$ shown in FIG. 3b, a boundary line position X of the reference model 21 is identified. Then, as shown in FIG. 4a, a brightness range Δb corresponding to the allowable error range ΔX is obtained. Then, when a shape inferiority inspection for the inspection object 23 is performed, it is checked whether a brightness value of each corresponding pixel in the inspection image 24 is included in the brightness range Δb. If the brightness value of the corresponding pixel in the inspection image 24 is included in the brightness range Δb of a corresponding pixel of the reference image, it is discriminated that the shape of the inspection object 23 is normal. Otherwise, it is discriminated that the shape of the inspection object 23 is abnormal.

Meanwhile, pixel noise existing in an image causes an error in an inferiority inspection work while a set of processes as described above are being conducted. FIG. 4b is a graphical view for explaining a process of obtaining a brightness range, $\Delta b'$, considering existence of the pixel noise, showing that $I(x) \pm \Delta n$ which is obtained by adding the pixel noise $\pm\Delta n$ to the pixel brightness value $I(x)$ of FIG. 4a.

In a case that pixel noise Δn exists, a boundary line position X corresponding to a brightness b' is given a range ΔX_1 as shown in FIG. 4b. Here, considering a position allowable error ΔX, the boundary line position becomes a range ΔX_2, which equals $\Delta X_1 + \Delta X$. Thus, the range of the

brightness including the position allowable error ΔX becomes $\Delta b'$.

When using the brightness range $\Delta b'$, a position of the boundary line actually distinguishable is $\Delta X'$ due the pixel noise. Thus, the distinguishable position range due to the pixel noise is increased from ΔX to $\Delta X'$. As the pixel noise is smaller, the distinguishable range $\Delta X'$ converges to ΔX.

The maximum value and the minimum value of the brightness range $\Delta b'$ obtained through the above processes are used in forming a maximum image U and a minimum image L. As described above, these two images are used as the reference image 22 for discriminating shape inferiority in the inspection image 24.

Assuming that an inspection image is Q, and the maximum image and the minimum image as the reference image are U and L, respectively, a function $C(Q;U,L)$ for discriminating shape inferiority in an object can be expressed as the following equation:

$$C(Q;U,L) = \Pi[\, l(i,j) \leq q(i,j) \leq u(i,j)\,] \quad \ldots(1)$$

wherein $l(i, j)$ is a brightness value of a pixel positioned at a coordinate (i, j) of the minimum image L, $q(i, j)$ is a brightness value of a pixel positioned at a coordinate (i, j) of the inspection image Q, and $u(i, j)$ is a brightness value of a pixel positioned at a coordinate (i, j) of the maximum image U.

In a case that a pixel P belongs to the background of the inspection image 24, that is, the boundary line of the inspection object 23 is l_1 and a pixel P belongs to the inspection image 24, that is, the boundary line of the inspection object 23 is l_3, an object shape inferiority calculation method performs the same procedure as in the case where a boundary line of an

inspection object is located on a pixel.

That is, a brightness range according to an allowable error in position is obtained from the graph of the pixel brightness *I(x)* with respect to the position as shown in FIG. 3b - the graph of FIG. 4b if pixel noise exists. Based on the judgment as to whether a brightness value of each corresponding pixel in an inspection object is included in the obtained brightness range, the shape inferiority of the inspection object is discriminated. That is, the minimum brightness value and the maximum brightness value in the obtained brightness range are used in forming the minimum image and the maximum image, respectively.

The pixel brightness values of the maximum image and the minimum image which are reference images, formed through the above procedure, are compared with the brightness values of corresponding pixels in the inspection image, to thereby discriminate whether the inspection object is inferior in shape or not.

In judging whether shape inferiority of the inspection object is discriminated, if brightness values of all the pixels belonging to the inspected area are within an allowable error range determined by the minimum image and the maximum image, it is discriminated that the inspection object is normal in shape. Otherwise, it is checked that the inspection object is abnormal in shape.

However, the inspection area which is a collection of pixels whose brightness values are compared, in the inspection image of the inspection object, can be a full area of the inspection image or only a local area thereof, as necessary, and the reference image, that is, the maximum image and the minimum image can also have pixel brightness values only in a necessary

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inspection area.

Meanwhile, the criteria to finally judge whether the inspection object is inferior in shape or not can be different as necessary, based on what the inspection object is. For example, pixels of 80% or more belonging to the inspection area have brightness values within the allowable error range, it can be judged that the inspection object is normal in shape.

The following Table 1 shows the experimental results using an image of a lead frame as shown in FIG. 5, following an object shape inferiority inspection method using a conventional measurement-comparison method and an object shape inferiority inspection method using a grayscale comparison method according to the present invention.

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Table 1

Experimental results from a conventional measurement-comparison method and a grayscale comparison method according to the present invention.

Inspection method	Conventional method	Method by the present invention
Calculation time	6msec/one-time measurement	0.4μsec/one-time measurement
Inspection area	Local area	Full area
Remarks	Measuring position: dependent upon experience of the skilled worker	1. Various applications available 2. Inspection on foreign matters and pollution available

As can be seen from the above Table 1, the conventional method consumes 6 msec for one time measurement whereas the method according

to the present invention consumes 0.4μsec. Thus, in a case that an image totaling to 300,000 pixels in the lead frame shown in FIG. 5 is inspected, the present invention method consumes 120 msec in measuring 20 portions at maximum, but the conventional method consumes 1,800 seconds (30 minutes) in measuring 20 portions at maximum. As such, the conventional method consumes a large amount of time, for which an inspection area has to be limited to a local area not the entire area.

As described above, the object shape inferiority inspection method according to the present invention reduces the conventional two-step process through measurement and comparison into a one-step process comparing grayscales of corresponding pixels. Accordingly, the time required for inspecting inferiority in shape of an object can be greatly reduced. A shape inferiority over the entire area of an object can be detected.

The object shape inferiority inspection method according to the present invention can be applied to a semiconductor manufacturing process which requires high-speed and high-precision since it can detect the shape inferiority as for an object having an allowable error of a subpixel unit. In addition, pollution occurring during a semiconductor manufacturing process and a product inferiority due to a foreign matter can be detected.

Although the present invention has been described in connection with a preferred embodiment thereof, it will be appreciated by those skilled in the art that additions, modifications, substitutions and deletions not specifically described may be made without departing from the spirit and scope of the invention as defined in the appended claims.

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